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AA 1619 GB

2. Patent application number

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JOHNSON MATTHEY PUBLIC LIMITED COMPANY
2-4 COCKSPUR STREET
TRAFALGAR SQUARE
LONDON SW1 5BQ

Patents ADP number (if you know it)

536 26 8 009

If the applicant is a corporate body, give the country/state of its incorporation

GB

4. Title of the invention

EXHAUST SYSTEM FOR LEAN BURN IC ENGINE
INCLUDING PARTICULATE FILTER

5. Name of your agent (if you have one)

ANDREW DOMINIC NUNN

"Address for service" in the United Kingdom
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Country

Priority application number
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Number of earlier application

Date of filing
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Claim(s)

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Abstract

1 -

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EXHAUST SYSTEM FOR LEAN BURN IC ENGINE
INCLUDING PARTICULATE FILTER

5 The present invention relates to an exhaust system for a lean burn internal combustion engine, and in particular it concerns such an exhaust system comprising a particulate filter.

10 Exhaust gases from lean burn internal combustion engines comprise particulate matter. For example, it is well known that diesel engines emit particulates, especially upon start-up and under heavy load, which can be observed with the naked eye. Modern lean burn gasoline engines also emit large numbers of very small ($<0.1 \mu\text{m}$ generally 10-100 nm) particulate matter (PM), which because of its small size is not observed by the naked eye.

15

 It is very well known that gas-borne particulates can cause health problems if inhaled. Concern about particulates has led to the introduction of various National or European regulations to control the quantity of particulates emitted from diesel engines. Johnson Matthey has patented and commercially introduced a device called a CRT[™] for 20 diesel engines, particularly heavy-duty diesel engines ((as defined by the relevant European, US Federal or Californian legislation) see EP-B-341832 and US-A-4,902,487, the entire contents of which are incorporated herein by reference)) which has made available a self-regenerating diesel filter device.

25

 The CRT[™] device embodies a process whereby nitrogen monoxide in the exhaust gas is oxidised to nitrogen dioxide and particulate matter on a filter is combusted in the nitrogen dioxide at temperatures of up to 400°C.

30

 It is also known to combust particulate matter of a filter in oxygen. However, temperatures of up to about 600°C are desirable in order to effect significant combustion of particulate matter to regenerate the filter. The combustion temperature in oxygen can be reduced somewhat by catalysing the filter.

A temperature rise in an exhaust gas in order to combust particulate matter in oxygen can be effected passively: the backpressure in the exhaust system is increased as more particulate matter is deposited on the filter. This, in turn, increases the load on the engine, leading to the required increase in exhaust gas temperature.

Alternatively, or in addition, active filter regeneration means can be employed to increase the exhaust gas temperature, e.g. fuel burners, electrical heaters, microwave heating or injection of combustibles into the exhaust gas alone or in conjunction with a warm-up catalyst, i.e. a catalyst for creating an exotherm.

Typically a particulate filter has a large open frontal area relative to the cross sectional area of a conduit for conveying the exhaust gas to the filter. In practice, the filter is disposed in a can or shell which is then mounted between an inlet and an outlet formed of the conduit. A diffuser section of a can or shell housing the filter or an inlet snorkel can be disposed between the inlet and the upstream face of the filter. From our investigations of diesel particulate filters we have observed that, despite the use of such diffusers, snorkels or the like, most of the exhaust gas will enter the filter at a point immediately opposite the inlet. Since, typically, a filter is cylindrical and the inlet conduit is arranged along the central axis thereof, a larger proportion of the particulate matter in the exhaust gas is concentrated in the central region of the filter than in regions peripheral to the central region. As a consequence, regions toward the periphery of the central region are generally cooler (because less hot exhaust gas contacts them) and increased backpressure in the central region leads to increased exhaust gas temperatures therein and accordingly increased combustion of particulate matter in the central region of the filter.

There are a number of problems with the prior art arrangements. Firstly, the filter is never adequately cleaned of particulate matter, because particulate matter deposited on the filter in regions peripheral to the central region are cooler than the central region and consequently are less likely to be combusted. This problem is compounded because certain filter materials are poor heat conductors e.g. cordierite and SiC (because a SiC filter is made up of a plurality of blocks separated by adhesive layers, which reduce thermal conductivity).

Secondly, the fact that a relatively small region of the filter is used for filtering particulate matter from the exhaust gas constrains the capacity of the system as a whole to treat particulate matter.

5 Thirdly, since not all of the filter is actively used to trap particulate matter, filter volume is wasted.

Fourthly, thermal gradients between a relatively hot central region of a filter and relatively cool peripheral regions can cause damage to the filter.

10

We have now found that it is possible to remove or reduce one or more of these problems by using a deflector to deflect at least some exhaust gas flowing in an exhaust system away from entering the filter at a point immediately opposite an inlet.

15

According to one aspect, the invention provides an exhaust system for a lean burn internal combustion engine, which system comprising a particulate filter disposed between an inlet and an outlet and a deflector disposed on the inlet side of the filter for deflecting at least some exhaust gas flowing in the system away from entering the filter at a point immediately opposite the inlet, which deflector comprising an upstream end having a first cross sectional area and a downstream end having a second cross sectional area, wherein the second cross sectional area > the first cross sectional area.

20

We appreciate that the use of the deflector may increase the temperature in the system at which the particulate matter is combusted and/or prolong the regeneration time. However, this is a problem encountered in many exhaust systems, e.g. diesel systems using high rates of exhaust gas recirculation and known active regeneration techniques, such as those mentioned above can be used, as necessary.

25

The present invention is advantageous in a number of respects. Firstly, the deflector is useful in that it can improve the efficiency of the filter to remove particulate matter from the exhaust gas because more of the filter capacity is being used. This can enable smaller capacity filters to be used (because the efficiency of the system to filter

30

particulate matter is improved) or it can extend the period required between active regeneration events, thus decreasing fuel penalty.

5 A further advantage is that the invention can elicit more efficient active regeneration. This is because the deflector not only improves particulate matter distribution across a filter, but it can also improve flow distribution of the heated exhaust gas across the filter. The more evenly distributed the exhaust gas flow, the more likely that the filter will be more evenly regenerated, i.e. at a point immediately opposite the inlet and in the regions peripheral thereto.

10

Vehicle manufacturers are increasingly finding difficulty in accommodating filters on a vehicle, particularly in underfloor locations. As a result, and in extreme circumstances, non-circular cross-sectioned filters are being employed.

15 The ability to even the exhaust gas flow across a filter is particularly advantageous for filters that are non-circular in cross-section, where poorly uniform flow patterns across the filter can lead to incomplete use of expensive filter volume and possible thermal stresses across the filter volume. The facility to reduce filter volume is also a distinct advantage if there are capacity constraints.

20

Therefore, in one embodiment, the deflector can be chosen to even the exhaust gas flow across a downstream non-circular cross sectioned filter. For example, the deflector cross section can be the same or a similar shape to the cross section of the filter.

25

In another embodiment, the deflector is a cone, i.e. the first cross sectional area is zero, or a frusto-cone.

30

In another embodiment, the deflector can comprise a flow-through substrate comprising at least two channels. The at least two channels in this substrate can either be parallel, e.g. as in Corning's ConturaTM substrate or, in another embodiment, non-parallel. Where the at least two channels are non-parallel, in one embodiment the cross sectional area of each channel on the outlet substrate end is greater than on the inlet

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substrate end. In a further embodiment, the channels converge towards a point on the inlet side of the substrate.

Alternatively, the deflector can comprise an outer surface for deflecting the exhaust gas. In this embodiment, the outer surface can be continuous or semi continuous, i.e. it may include one or more apertures to enable exhaust gas to pass through.

In the cone or frusto-cone deflector embodiment, the cone or frusto-cone can be squashed in at least one dimension about a central axis and need not be symmetrical along any plane intersecting that central axis.

The deflector can be made of any suitable material. For example, it can be made from a ceramic, e.g. cordierite, or SiC. In one embodiment it is made from metal e.g. FecralloyTM or steel or other materials with similar properties. Where the deflector is made from metal it can be made of thin metal foils, generally layers of corrugated metal foil sandwiched between flat metal foil and formed into honeycomb structures by coiling the layers together. The resulting array of channels is sinusoidal in cross-section because they are formed in part from the corrugated foil.

Where the deflector is catalysed, in one embodiment the catalyst is for oxidising NO in the exhaust gas to NO₂. Such catalysts are known and include an optionally supported, e.g. on alumina, at least one platinum group metal (PGM), e.g. platinum. In this arrangement, particulate on the filter downstream can be combusted in the NO₂ at temperatures of up to 400°C. Such a method is described in our EP-B-0341832, first mentioned above.

Exhaust gas flowing in an exhaust system will always try to take the path of least resistance, and typically this is to enter the filter at a point immediately opposite the inlet. In certain systems in which the filter is catalysed, it can be advantageous to improve combustion performance of the particulate matter away from the region immediately opposite the inlet by additional means. Such means can include, graduatedly increasing the catalyst loading from the region immediately opposite the inlet towards the periphery

thereof and/or using low sulphur fuel e.g. fuel that produces exhaust gas having a sulfur content of less than 20 ppm, such as less than 10 or 5 ppm sulfur.

5 In a further embodiment applicable to both catalysed and non-catalysed filters, the pressure drop across the filter in the region immediately opposite the inlet can be increased by blocking the filter pores with a suitable washcoat, which can be the catalyst washcoat. In this embodiment, the pressure drop can be graduatedly increased across the filter towards the region immediately opposite the inlet by increasing the washcoat loading, or fineness of the washcoat particles. In a further embodiment, an increased
10 pressure drop can be provided by blocking at least one channel in the region at both ends, whereby an exhaust gas would need to cross two channel walls to reach an outlet.

15 Of course the inlet need not be positioned opposite the centre of the filter, nor necessarily need the filter be cylindrical. Where the filter is non-cylindrical, it can be oval or "racetrack" or any appropriate configuration.

According to a further embodiment, the filter is a wall-flow filter and can be made from cordierite or SiC, for example. Optionally, the filter can comprise a catalyst. Where the filter is catalysed, the catalyst can comprise an optionally supported, e.g. on
20 alumina, at least one PGM, such as platinum.

25 According to a further aspect, the invention provides an internal combustion engine including an exhaust system according to the invention. The engine can be a diesel engine, for example a light- or heavy-duty diesel engine.

30 According to a further aspect, the invention provides a method of more evenly distributing particulate matter in a flowing exhaust gas across a particulate filter disposed in an exhaust system, which method comprising contacting the exhaust gas with a deflector disposed on an inlet side of the filter thereby to deflect at least some exhaust gas flowing in the system away from entering the filter at a point immediately opposite the inlet, wherein the deflector comprises an upstream end having a first cross sectional area and a downstream end having a second cross sectional area, wherein the second cross sectional area > the first cross sectional area.

In order that the invention may be more fully understood, embodiments thereof will be described by reference to the accompanying drawings in which:

Figure 1 is a schematic sectional view of an exhaust system including a filter and
5 a deflector according to one embodiment according to the present invention;

Figure 2A is a schematic cut-away view of a second deflector embodiment for use in the present invention comprising a Corning ConturaTM substrate;

10 Figures 2B, 2C are schematics of two ConturaTM substrates, each substrate being disposed in a diffuser section having cone of different cone angles;

Figure 2D is an alternative substrate to Figures 2B and 2C comprising a dome shaped front face disposed in a diffuser section; and
15

Figure 3 is a schematic view of a third deflector embodiment for use in the present invention.

Figure 1 shows a schematic sectional view of an exhaust system (10) for a lean
20 burn internal combustion engine, which exhaust system comprising a cordierite wall flow filter (12) of conventional construction. Such wall flow filters comprise a plurality of channels arranged in a honeycomb configuration wherein at each end of the filter block alternate channels are blocked, such that the arrangement of blocked and open channels at either end resembles a chess board.

25

A conical deflector (14) is disposed upstream of the filter, the arrangement being such that the narrow end of the cone is on the upstream side. The conical deflector (14) is made of a metal, such as FecralloyTM or steel and presents a continuous surface for exhaust gas flowing in the exhaust system (10) to flow thereover.

30

The deflector (14) and filter (12) are housed in a steel shell or can (16) which includes an inlet (18) upstream of the deflector and an outlet (not shown) downstream of the filter. As is conventional in the art, the filter can be held in position and insulated

from the shell using a mat disposed between an internal surface of the shell (16) and an external surface of the filter (12) (not shown). Conical deflector (14) is suspended from the internal surface of the frusto-conical section (22) of the shell (16) using elongate steel struts (not shown) each extending in the axial flow direction of the exhaust gas. Where
5 two struts are used, each can be arranged opposite the other i.e. at 180° ; where three struts are used, these may be arranged at 120° from each other; and where four struts are used, they can each be 90° from its immediate neighbours.

10 Inlet (18) is connected to a conduit (20) for conveying the exhaust gas from the engine and optionally via upstream processes for treating the exhaust gas.

In practice, exhaust gas flowing in conduit (20) is conveyed to inlet (18) where it contacts the tip of cone deflector (14) arranged along the central axis of the frusto-conical section (22) of the shell (16). The internal surface of the frusto-conical section of
15 the shell (16) and the external surface of the cone deflector (14) are configured such that the gap therebetween is substantially uniform. The cone thus deflects the exhaust gas radially outwardly. As the exhaust gas reaches the trailing edge of the cone deflector (14), it is caused to flow inwardly behind the cone deflector (14) towards the lower pressure applied by positioning the cone deflector (14) in the flow path of the exhaust
20 gas. This centrally directed flow causes turbulence which can in turn promote a desirable more even distribution of exhaust gas flow across the front face of the filter (12).

25 In a further embodiment, the surface of conical deflector (14) is discontinuous, i.e. it includes one or more apertures through which the exhaust gas can flow.

Figure 2A shows an alternative deflector which can be used in place of cone deflector (14) in Figure 1. It comprises the forward section of a ConturaTM substrate, i.e. a flow-through monolith having a plurality of unblocked channels arranged in parallel. The ConturaTM substrate includes a centrally arranged flat front face with a
30 conical section extending toward the circumference of the outer substrate surface therebehind. In this embodiment, the frusto-conical section (22) of the shell (16) can be referred to as a diffuser (24). Diffusers of different configurations and their use are known in the art.

referred to as a diffuser (24). Diffusers of different configurations and their use are known in the art.

5 Figures 2B and 2C illustrate schematic sectional views of different Contura™ substrates having different cone angles and showing the arrangement of the substrate in diffuser (24). Figure 2D shows a schematic sectional view of an alternative substrate comprising a dome-shaped front face and is disposed in a diffuser, similarly to the Contura™ substrates shown in Figures 2B and 2C.

10 Figure 3 shows a further deflector embodiment, which can be used instead of the deflector (14) in Figure 1. In this embodiment, the deflector comprises a plurality of frusto conical tubes arranged in parallel. This embodiment can be made from metal, such as thin metal foils of Fecralloy™ and can be made by sandwiching layers of corrugated metal foil between flat metal foil and forming it into a honeycomb structure by coiling
15 the layers together. The resulting array of channels is sinusoidal in cross-section because they are formed in part from the corrugated foil. In practice, this embodiment can be disposed in e.g. a metal housing comprising an uninterrupted surface. Alternatively the deflector can be housed in a section of the can or shell.

20 A catalyst washcoat can be applied to the deflector such as platinum on a high surface alumina support using techniques known in the art. Such catalyst washcoat can be an appropriate platinum loading for promoting NO oxidation and in turn to promote combustion particulate matter on the filter in NO₂ at temperatures of up to 400°C according to the process described in EP 0341832 mentioned above.

CLAIMS:

1. An exhaust system for a lean burn internal combustion engine, which system comprising a particulate filter disposed between an inlet and an outlet and a deflector disposed on the inlet side of the filter for deflecting at least some exhaust gas flowing in the system away from entering the filter at a point immediately opposite the inlet, which deflector comprising an upstream end having a first cross sectional area and a downstream end having a second cross sectional area, wherein the second cross sectional area > the first cross sectional area.
2. An exhaust system according to claim 1, wherein the deflector is a cone or a frusto-cone.
3. A system according to claim 1 or 2, wherein the deflector comprises a flow through substrate comprising at least two channels.
4. A system according to claim 3, wherein the cross sectional area of each channel on the outlet substrate end is greater than on the inlet substrate end.
5. A system according to claim 3 or 4, wherein the channels converge towards a point on the inlet side of the substrate.
6. A system according to claim 3, wherein the at least two channels are parallel to one another.
7. A system according to claim 1 or 2, wherein the deflector comprises an outer surface for deflecting the exhaust gas.
8. A system according to claim 7, wherein the outer surface includes at least one aperture for exhaust gas to flow through.
9. A system according to any preceding claim, wherein the cone or frusto-cone is squashed in at least one dimension about a central axis.

10. A system according to any preceding claim wherein the deflector is made of a metal.
- 5 11. A system according to any preceding claim, wherein the deflector comprises a catalyst.
12. A system according to claim 11, wherein the catalyst is for oxidising NO in the exhaust gas to NO₂.
- 10 13. A system according to claim 11 or 12, wherein the catalyst comprises an optionally supported at least one platinum group metal (PGM).
14. A system according to claim 13, wherein the PGM includes platinum.
- 15 15. A system according to any preceding claim, wherein the inlet is immediately opposite the centre of the filter.
16. A system according to any preceding claim, wherein the filter is a wall-flow
- 20 filter.
17. A system according to any preceding claim, wherein the filter is of non-circular cross-section.
- 25 18. A system according to any preceding claim, wherein the shape of the deflector in cross-section is the same as or similar to the shape of filter in cross-section.
19. A system according to any preceding claim, wherein the filter comprises a catalyst.
- 30 20. A system according to claim 19, wherein the catalyst comprises an optionally supported at least one platinum group metal (PGM).

21. A system according to claim 20, wherein the PGM includes platinum.
22. An internal combustion engine including an exhaust system according to any preceding claim.
- 5 23. An engine according to claim 22, wherein it is a diesel engine.
- 10 24. A method of more evenly distributing particulate matter in a flowing exhaust gas across a particulate filter disposed in an exhaust system, which method comprising contacting the exhaust gas with a deflector disposed on an inlet side of the filter thereby to deflect at least some exhaust gas flowing in the system away from entering the filter at a point immediately opposite the inlet, wherein the deflector comprises an upstream end having a first cross sectional area and a downstream end having a second cross sectional area, wherein the second cross sectional area $>$ the first cross sectional area.
- 15 25. An exhaust system substantially as described herein with reference to the accompanying drawings.
- 20 26. An internal combustion engine substantially as described herein.
27. A method substantially as described herein with reference to the accompanying drawings.

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EXHAUST SYSTEM FOR LEAN BURN IC ENGINE
INCLUDING PARTICULATE FILTER

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Abstract

10 An exhaust system (10) for a lean burn internal combustion engine comprises a particulate filter (12) disposed between an inlet (18) and an outlet and a deflector (14) disposed on the inlet side of the filter for deflecting at least some exhaust gas flowing in the system away from entering the filter at a point immediately opposite the inlet, which deflector comprising an upstream end having a first cross sectional area and a downstream end having a second cross sectional area, wherein the second cross sectional
15 area > the first cross sectional area.

[Fig. 1]

1 / 2

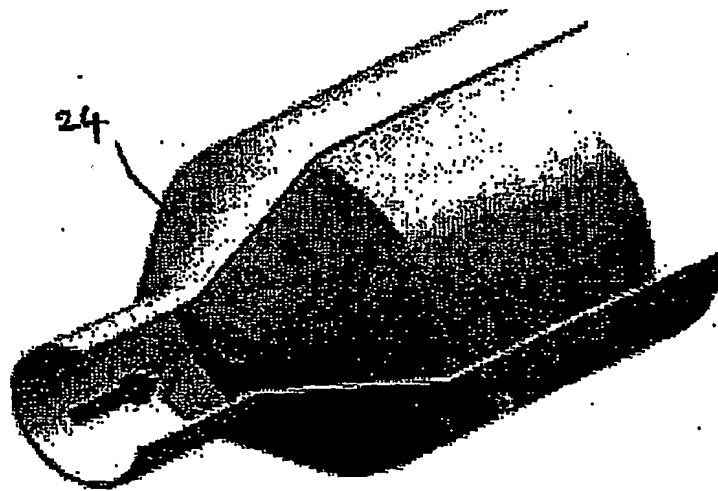
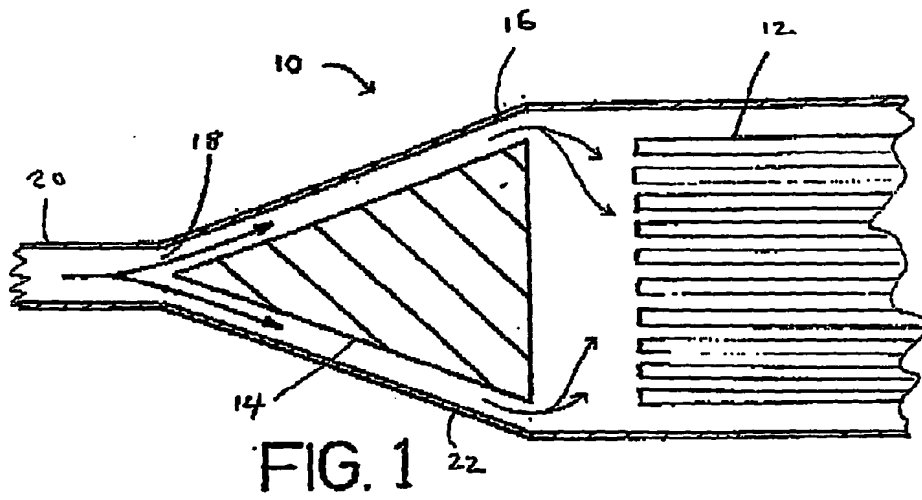


FIG 2A

2/2

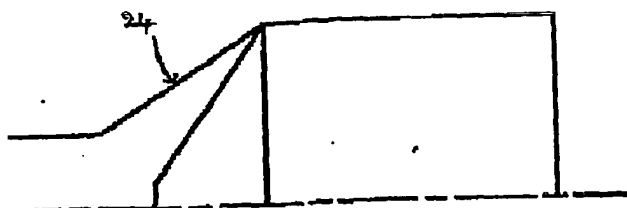


FIG. 2B

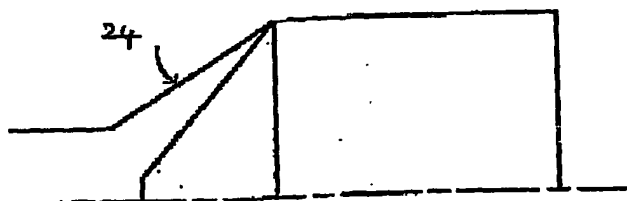


FIG. 2C

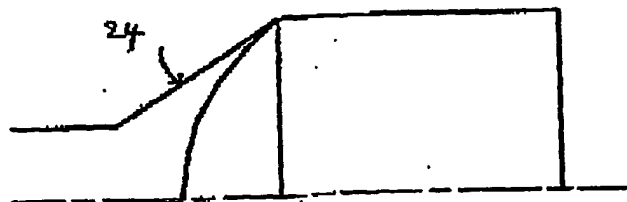


FIG. 2D

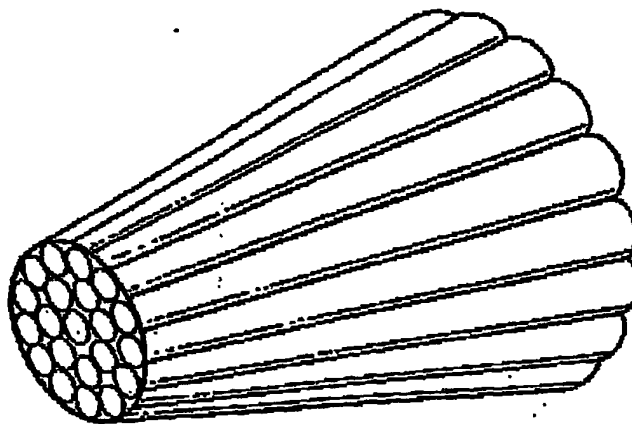


FIG. 3

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